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Some properties of BSCCO-Ag added high temperature superconductors

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Abstract The samples of $(Bi\text{-}Pb)_2Sr_2Ca_2Cu_3O_{10+\delta}$ system were prepared by conventional solid state reaction method with silver addition from 0% to 50%. Some interesting results have been obtained. It has been observed from the X-ray diffraction data that the enhancement in 2212 phase and reduction in 2223 phase may exhibit the suppression of T_c at certain concentration of Ag wt%. It is also viewed from X-ray diffraction and intensity data that the addition of silver of 30% to 40%, does not deteriorate the sample quality of (2223) compounds. But addition of silver beyond this, may lead to formation of 2212 phase in increasing proportion.

Keywords : Superconductivity, enhancement in 2212 phase, volume fraction

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After the discovery of high temperature oxide superconductors, major work concentrated on the application areas like transmission, high magnetic fields, superconducting magnets, superconducting wheels *etc.* Silver is very useful element in preparing superconducting wires and tapes. Silver remains an additive material in the conventional $Y_1Ba_2Cu_3O_{7-\delta}$ and Bi-Sr-Ca-Cu-O (BSCCO) compounds [1-3] and improves the properties of superconductors. The experimental work on superconductors shows improvement in current capacity of the materials. It acts as additive material and improves the mechanical strength and reduces porosity [4, 5]. Transition temperature is found to decrease when percentage of silver increases. Some interesting results were obtained when detailed study of silver addition of the samples was done. The addition of Pb to bismuth compound was found to stabilize the 2223 phase of the system. For the concentration of Ag studied in this paper, show the enhancement of 2212 phase with Ag addition.

The samples of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ system with Ag addition from 0% to 50% were prepared by ceramic route [6-9]. These samples were prepared by mixing stoichiometric amounts of oxide powders Bi_2O_3, Pb_2O_3, $SrCO_3$, $CaCO_3$ and CuO with high purity *i.e.* 99.99% (Aldrich Make). The stoichiometry is taken with accurate form of the powders. Then pure silver is added with appropriate form from 0 wt% to 50 wt%. Initially, powders were ground for 3 hours; then the first calcination was done at 810°C for 24 hours. The black colour was observed for all the powders. Again these powders were ground for 3 hours, second calcination was done at 820°C for 48 hours, cooled slowly upto room temperature. Subsequently, powders were pressed into pellets under the pressure of 5 to 7 tonnes and sintered at 850°C for 120 hours followed by slow cooling in Carbolite tubular furnace upto room temperature.

Electrical resistivity of the system for all Ag-added samples were determined as a function of temperature. The values of $T_{c(0)}$, $T_{(onset)}$ and ΔT_c are listed in Table 1. It is observed from Table 1 that the transition width for all samples is sharp. Figure 1 shows the resistivity graphs on the pure 2223-Ag samples with Ag% varying from 10% to 50%. From resistivity graph, we see that there is a single step transition for a sample without Ag. With addition of silver, we see a double-step effect. This may be due to one or two layers of 2212 phase which remain preferentially at the common (001) twist boundaries [10] and produce a double-step in the T_c transition. We feel upto 30-40% of Ag addition

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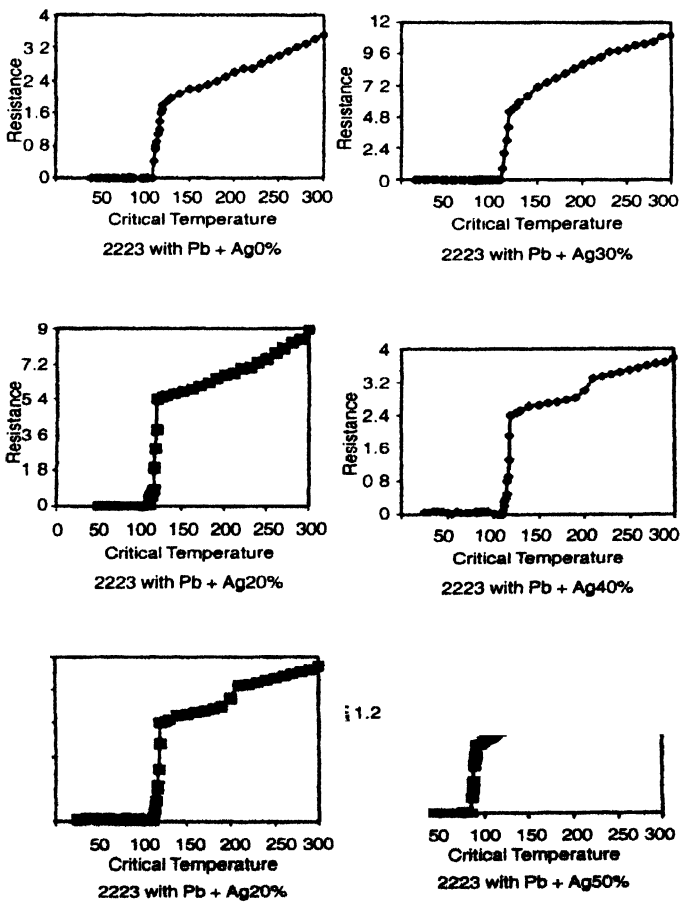
Table 1. Resistivity data for $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi-2223) Ag-added system

Ag%	$T_{c(0)}$	$T_{c(onset)}$	$\Delta T_c = T_{c(onset)} - T_{c(0)}$
00	110	120	10
10	110	115	05
20	110	115	05
30	110	113	03
40	85	90	05
50	80	85	05

that the superconductivity is sustained through 2223 grains. From Table 1 we see that there is no change in T_c upto 30% Ag-addition, then deformation of lattice starts. Either oxygen-content is reducing or the low T_c phase is increasing. It is difficult to prepare pure Bi-2223 compound. As we start adding Ag, we see that reflections corresponding to Bi-2212 phase become more prominent which can be seen by comparing Ag10% wt addition and Ag50% wt addition samples [11-12]. The peak intensity of Ag10% wt sample is higher than that of Ag50% wt



system.

sample. On addition of Ag% wt, the peak intensity gets reduced. Also it is wellknown that Ag goes along grain boundaries and Ag peaks become more prominent as Ag% increases [13]. The SEM photographs also confirm this fact [13]. The X-ray diffraction patterns of Bi-2223-Ag-added samples are shown in Figure 2. The lattice parameters for high T_c phase (2223) and low T_c phase (2212) are calculated from X- ray diffraction data and listed in Table 2 and 3 respectively. From Table 2, we see that a, b and c values of lattice parameters are constant up to 30% of silver addition and then there is deformation. From X-ray diffraction and intensity data, we have calculated the volume fractions for (2223) and (2212) phases and listed in Table 4. The volume fractions for both the phases *versus* Ag% is plotted and shown in Figure 3. It is clear that from these results, the addition of more silver tends to increase the low T_c phase *i.e.* 2212 phase in the samples beyond 40 wt% of Ag.

Table 2. Variation of lattice parameters of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi 2223) Ag-added system.

Ag%	a (A)°	c (A)°	Volume cell $(A°)^3$
00	5.40	36.996	1078.803
10	5.40	36.996	1078 803
20	5.42	36.996	1986 809
30	5 42	36 996	1086.809
40	5.41	37 104	1085 963
50	5 41	37 650	1101.944

Table 3. Variation of lattice parameters of $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10+\delta}$ (Bi-2212) Ag-added system

Ag%	a (A)°	c (A)°	Volume cell $(A°)^3$
00	3.816	30.696	446.991
10	3.816	30.732	447 515
20	3.816	30 732	447.515
30	3.816	30.855	454.028
40	3.812	30.767	447.085
50	3.776	31.000	442.003

Table 4. The relative intensity and volume fraction of 2212 and 2223 phases of (Bi-2223) Ag-added system.

Ag%	Relative intensity of 2212 phase	Relative intensity of 2223 phase	Volume fraction of 2212 phase (%)	Volume fraction of 2223 phase (%)
00	64	69	48.12	51.87
10	64	69	48.12	51.87
20	50	69	42.02	57.98
30	49	84	36.84	63.15
40	40	75	34.78	65.21
50	82	77	51.57	48.42

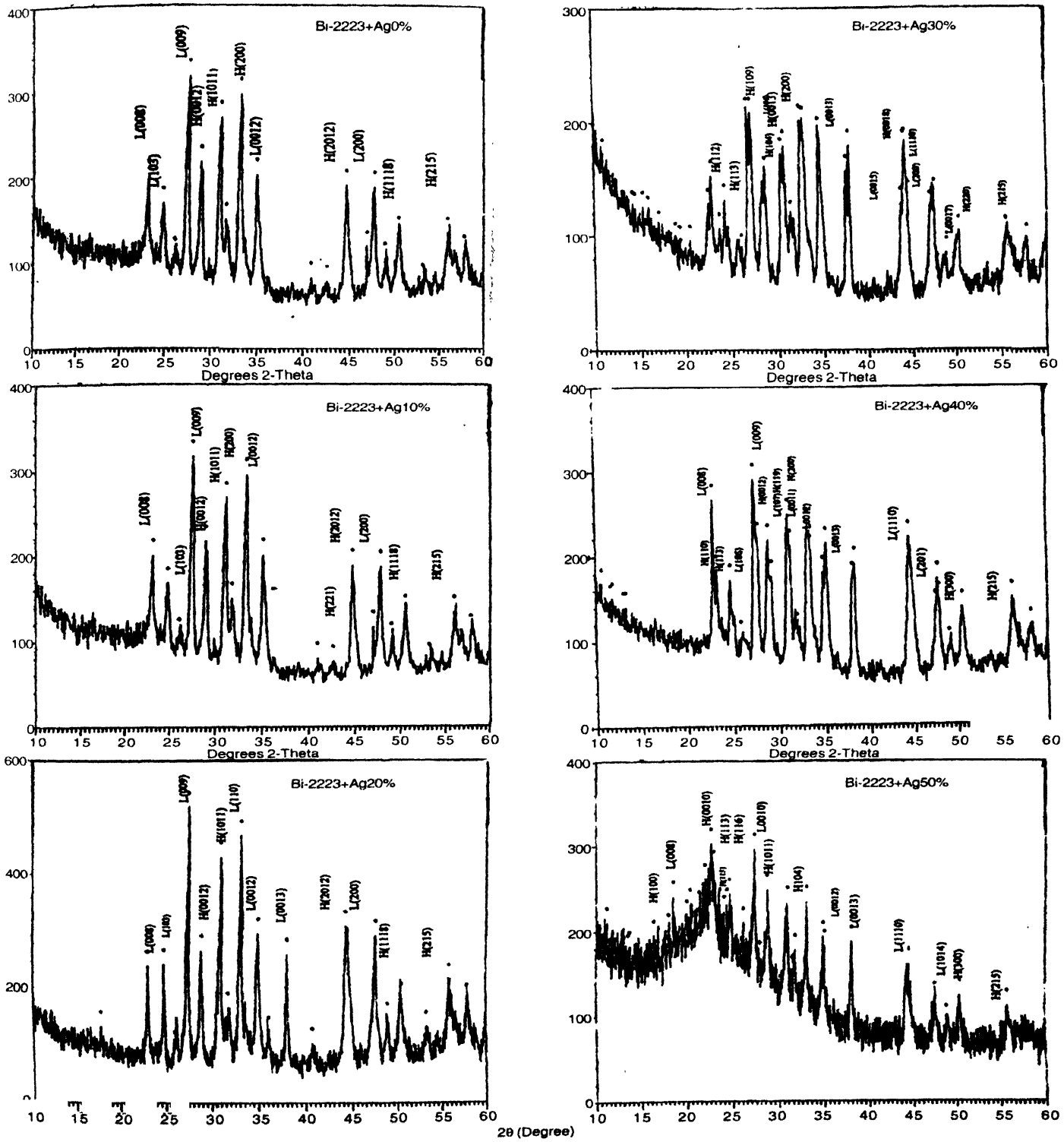


Figure 2 X-ray diffraction patterns of Bi-2223 + Ag wt% samples prepared by conventional solid state reaction route. It is observed that the Bi-2223 phase gets reduced and Bi-2212 phase is enhanced on addition of Agwt%. If we compare Ag0% sample with Ag50% sample, extra peaks have been observed in Ag50wt% sample, which are absent in Ag0wt% sample. From this, one may conclude that the number of peaks goes on increasing while peak intensity goes on decreasing.

Studies of addition of silver in BSCCO (2223) compounds have become very important from the point of view of technological applications [14-17]. We note that addition of silver

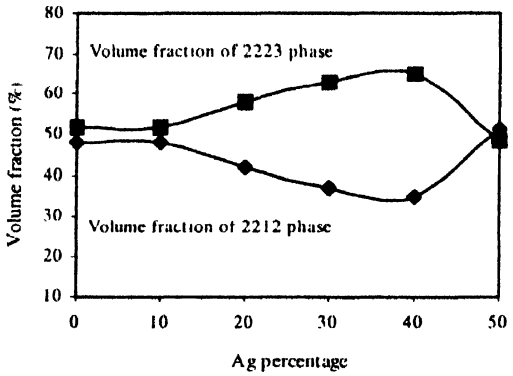


Figure 3. Volume fraction (%) of both phases *versus* Ag% is plotted The volume fraction of 2212 phase is increased beyond 40wt% of Ag while the volume fraction of 2223 phase decreases beyond 40wt% of Ag From this, one can conclude that the T_c of the system may decrease due to increase in volume fraction of 2212.

upto 30% of weight will not alter T_c, this will give mechanical strength and reduce porosity from Table 4, of volume fraction, we see that high T_c (2223) phase is stabilized by silver. Beyond 40%, we see the increase in lattice parameter c and cell volume, which reflects deformity in the structure. However, the volume fraction should show that beyond 40wt% of Ag, the high T_c phase decreases and low T_c phase increases. It may be possible cause for the reduction in T_c. Hence, addition of silver beyond 40wt% is not advisable.

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